CMVA Alignment Certification Program

Machinery Alignment of Rotating Shafts Level One and Level Two Performance Objectives

These performance objectives define the knowledge a certified individual should be able to perform, when aligning rotating shafts, during a machine unit installation (e.g. pump and motor), whether it be a new installation, re-installation, or as part of a preventative maintenance check. These objectives are based directly from the ANSI/ASA S2.75-2017/Part 1 & 2 standard and were prepared by members of CMVA's Technical Training Committee. All exams have the same percentage of questions per major topic as is shown in the heading of that topic. This document is available on www.cmva.com to members of CMVA. Check often for the most current version.

Prerequisites

Level	**1**	**2**
Minimum training hours	14	26 (14+12)
Minimum on-the-Job-training/experience (months)	6	12
Number of questions	100	100
Number of hours allowed	2	2

The pass mark of exams is 70%.

The ANSI/ASA S2.75-2017/Part 1 & 2 standard is the application of alignment concepts concerning relative positions of rotating shafts connected by mechanical means. It contains specific tolerances, factors affecting alignment, and an overview of various measurement methods, following the core technical components of "Measure, Analyze, Correct, and Document".

This standard covers the general configuration of two machines horizontally mounted using a four-bearing system with rotating shafts only.

The alignment of rotating shafts can be viewed as a process or a series of four stages: Stage One - Preparation; Stage Two - Inspection; Stage Three - Measurement and Correction; and Stage Four – Commissioning as per Appendix B.

Level One – Alignment Specialist Requirements

A certified level one alignment specialist will be able to perform shaft to shaft alignment using dial alignment method or a laser alignment tool on two rotating shafts coupled and un-coupled.

Skills and knowledge will include:

1. Alignment Principles, Tolerances, and Terminology as per Appendix A.
2. Understand and know the four-stage process of the alignment of rotating shafts including Preparation, Inspection, Measurement/Analysis/Correction and Commissioning as per Appendix-B.
3. Understand and know Potential consequences of not following this standard include accelerated wear of machine components (bearings, couplings, and seals), shortened machine life, unscheduled outages, and hazards to personnel and the environment.
4. Understand and know how to remove machine stress from a machine in order to have the machine shaft in a neutral position.

The requirement is the alignment of two shafts, from their neutral position to an attained set tolerance, using any of the listed tools/instruments.

Note: some tools are used during the rough-in stage, but a quantifiable tool is needed to verify attaining a set tolerance.

Level Two – Alignment Specialist Requirements

A certified level two alignment specialist will be able to perform shaft to shaft alignment using a laser alignment tool or dial indicator on two rotating shafts coupled and uncoupled. A level two alignment specialist should have a working knowledge of alignment applications including one shaft fixed (non-rotating) and both shafts fixed (non-rotating). They will also have the working knowledge to trouble-shoot, understand, and overcome most alignment situations.

Skills and knowledge will include:

1. Level 1 skills and knowledge (and certificate)
2. For laser alignment methods, at a minimum, the standard 9-12-3 method should be used.
3. For dial indicator methods, Rim and Face or Reverse dial using graphical and mathematical calculations as per Appendix C.
4. Demonstrating graphical/modeling including bolt-bound and base-bound options and results as per Appendix C.
5. From given machine dimensions, material and temperature values, perform a calculation and give the result in foot value targets as per Appendix C.

Appendix A - Alignment Principles, Tolerances & Terminology

Measurement methods and tools to determine offline shaft centerline positions.

~~List~~ the four shaft rotation choices in order of preference.

Alignment tolerance principles.

1. Describe a four-bearing set.
2. Define the acronym CML.
3. What is span?
4. What is offset?
5. What is angle?
6. Describe a flex plane.
7. Define TIR.
8. What is gap?
9. What is collinearity?
10. What is a tolerance?
11. What repeatability?

Know and state tolerances for:

1. Levelness
2. Flatness
3. Coplanarity
4. Shaft runout
5. Pipe strain
6. Soft foot
7. Shaft centerline to shaft centerline alignment (three tolerance acceptance levels for short flex planes and spacer shafts. Permissible residual misalignment.

Measurement repeatability:

1. Know the difference between repeatability and calibration.
2. Know the repeatability value that should be demonstrated to be compliant.
3. Know the repeatability value that is desirable when taking initial measurements when some gross misalignment is present.
4. Know the factors that may influence measurement repeatability.

Measurement Repeatability section referenced in section 5.3 ANSI standard

Factors affecting measurements.

1. Know what is required to be able to align the centerline of each shaft.

2. Know what is required in order to measure shaft or hub runout.
3. Identify the factor that can elastically bend (deflect) shafts resulting in erroneous results.
4. Know about potential errors that can occur when taking axial measurements.
5. Describe the issue known as brackets sag and how to compensate for it.
6. List the tools deemed acceptable for rough alignment only.
7. List the tools/instruments that require and do not require calibration.

Appendix B – Four Stages of the Alignment of Rotating Shafts

The alignment of rotating shafts can be viewed as a process or a series of four stages: Stage One - Preparation; Stage Two - Inspection; Stage Three - Measurement and Correction; and Stage Four - Commissioning.

Stage One - Preparation:

1. What safety precautions should be taken?
2. Have an understanding of the possible issues introduced with machinery installation, the factors that can influence the position of the shafts and their impact on the alignment.
3. Know the requirements of the machine and the expected end results (throughput).
4. Know the history of the machine (if available).
5. Gather the relative information needed, for example what is the expected range for RPM, operating machine temperature, and horse power.
6. Know what additional tools/equipment will be needed to achieve the correct installation subject to the condition of the equipment and baseplate. An example could be machine lifting equipment (jacks, chain falls, slings, pry bars, etc.).
7. Understand the acceptable alignment tools, measurement tools and instruments needed to take accurate measurements with a strong understanding of their use. Examples of tools are straightedges, micrometres, levels, dial indicators, laser alignment systems (note: if a laser system is used, the operator should have an understanding of how in principle it works and be aware of its condition/calibration requirements.)

Stage Two - Inspection:

1. Machinery structural supporting system. Know how to complete a full system inspection including such items as the support mechanism of a piping structure and the integrity of a machine base.
2. List the acceptable tools/instruments used to measure them.
3. Know if the machine or machines are in a state of good repair.
4. Identify present and potential machine stresses.

5. Know what specialized technologies that may be needed (for example, vibration phase analysis or dye penetrant crack test, IR, temperature, Ultrasound).
6. Machinery degradation
    - Machinery degradation issues such as excessive clearances, looseness or bearing damage must be addressed before any alignment work is done. An assessment should be done including, for example, a bearing lift.
7. Alignment needs assessment
8. The recommendation is that all machine with rotating shaft be aligned. An assessment of alignment data should be used based on horse power, work being done and RPM. Assessment should be done during new installation and as part of maintenance work (example: the removal overhaul and re-fitting of a machine unit, or as part of a Preventative Maintenance program confirming alignment results).
9. An assessment can also be done when machine indicates a change in operation (example: higher noise level). Note that if alignment work is done in this situation it will not repair any wear or damage that has occurred.

Stage Three – Measurement, Analysis and Correction:

1. Have a strong understanding of the alignment work process, whether for a new installation, a remove and refit repair, or a preventative maintenance task.
2. Define the process and order of measuring, analyzing and correcting:
    1. Machinery structural supporting system (base flatness, level and coplanarity).
    2. Shaft runout**.**
    3. Coupling hub runout**:**
        - Know the different requirements in relation to the rotating center line.
        - Know the technique of avoiding the error of hub runout when aligning shafts.
    4. Pipe and conduit strain**.**
        - Pipe strain, conduit strain, duct strain, and other external forces create machine strain/stress and distortion. Know the magnitude of the measured tolerance, the directional plane and the location of the measurement location.
    5. Soft foot
        - Know what a soft foot condition is
        - Know the effects of soft foot.
        - Know three types of anomalies that create soft foot.
        - Be able to give one external stress/strain or load that gives symptoms similar to soft foot.
        - Know the location and acceptable measurement method.
    6. Offline to Running (OLTR) machinery movement (Level 2 only.)
    7. Shaft centerline to shaft centerline alignment
        - Alignment condition assessment. An assessment of a machine can be done when it is in operation. List the recommended observations and measurements that should be used.
        - For laser alignment methods, at a minimum, the standard 9-12-3 method should be used.
        - For dial indicator methods, Rim and Face or Reverse dial can be used.

Shims

1. Know the percentage of a machines foot that has to be supported by shim.
2. Affirm the recommendations of, shim accuracy, the total amount used and any other pertinent information regarding shims.

Correcting misalignment conditions

1. In order to correct misalignment one or both of the machines have to be moved. Know the order and procedure for correcting and moving machinery.

Equipment hold-down bolts [foot bolts]

1. List the items for hardware inspection.
2. Describe the bolt tightening sequence.
3. What is the allowable amount of shaft movement when tightening machines down?

Controlled movement techniques

1. Know if it is necessary to measure with a dial indicator or laser/detector system the live movement when moving a machine with jackscrews (jacking bolts).
2. What is the as left position of the jackscrews?

Axial spacing or coupling gap

When machines are moved the axial or coupling gap can be affected.

1. Know axial spacing dimensions.
2. Know what axial thrust Is.

Stage Four - Commissioning:

1. Know the importance of the machine meeting the required output.
2. Document all that was measured, including as found/as left data, final operating temperature and verification of machine movement.
    - List the recommended items that should be in the report. Including calibration due on all applicable measurement instruments.

Appendix C – Additional Level 2 information

(7.3 Alignment modeling)

Note: a model of two machines and their shafts positions can be constructed that represent a misaligned condition of the shafts. This can be a simple line drawing using graphical plotting technique. This is a very good visual aid to the alignment technician.

1. Create a graphical plot using the supplied data and give the suggested required adjustment for the moveable machine correction.
2. Add the given OLTR to the stationary machine and re-plot.
3. Demonstrate bolt and base bound options to align the shaft.
4. What is Validity rule?

(8.1 Thermal growth calculation

Describe process of measuring thermal growth at machines feet

Know and define calculation (T x L x C) using differential temperature values (running – ambient) (T), the length or distance between feet and shaft (L) and coefficient of thermal expansion based on material (C).

(8.2 Bolt bound/base bound)

1. Define being bolt bound and base bound.
2. Describe the preferred way of correction.
3. List alternative methods.

Normative references

ANSI/ASA S2.75-2017/Part 1- Shaft Alignment Methodology, Part 1: General Principles, Methods, Practices and Tolerances

ANSI/ASA S2.75-2017/Part 2 – Shaft Alignment Methodology, Part 2: Vocabulary